From thermal comfort to conflict: the contested control and usage of domestic smart heating in the United Kingdom

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Abstract: The possible benefits of the ongoing digitization and enhancement of energy services with smart technologies has been extensively documented in the literature, but is there also scope for smart systems to lead to household conflicts? In this study, using data from the Energy Systems Catapult's Living Laboratory, we explore a fundamental energy service (heat) utilized in buildings from a novel angle: social conflict. We define social conflict as oppositional goals, aims, and values held by different people. We draw from three sets of primary data—diary studies and blogging via mobile ethnography, telephone interviews, and household interviews—involving 100 homes across Birmingham (West Midlands), Bridgend (Wales), Manchester (Greater Manchester), and Newcastle (Northumberland) in the United Kingdom. We identify five different forms of "thermal conflict": parents versus children, hosts versus guests, roommates vs. each other, landlords vs. tenants, and couples vs. each other. After documenting the presence of 20 specific examples of conflict, we then discuss how they differ by location (intrinsic vs. extrinsic), type (preference, attitude, and variety) and values (hedonic, egoistic, altruistic, biospheric). We conclude with implications for energy and buildings research and policy more broadly, noting that thermal conflicts in the home differ in their location or cause. Thermal conflicts differ in their severity, with some occurring as more minor annoyances over preferences, but others relating attitudes, where heating actions or preferences become a proxy for something else, and emit strong feelings about how a household members views another person as lazy, careless or wasteful. A variety of values remain attached to heating conflicts, with hedonic (self-comfort, self-pleasure), egoistic (saving money, control) and altruistic (helping others, making others comfortable) values almost evenly reflected across our examples.

Keywords: smart energy; heating and cooling; living lab; energy practices; smart homes; big data

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1. Introduction

It has become well established that building energy infrastructure in controversial areas, or the unfair siting of energy projects, can lead to social conflict, community discord, and "Not-in-my-backyard" sentiments (Westernberg et al. 2015; Komendantova and Battaglini 2016; Eaton et al. 2019; Černoch et al. 2019). This body of evidence all emphasizes how sources of energy supply can lead to various degrees of social conflict.

However, far less explored is how conflicts may arise not on the energy supply side, but on the energy demand side, concerning energy consumption and use. Much literature has focused on examining how household energy consuming behaviors form (e.g. Ellegård and Palm, 2011; van der Werff and Steg, 2015), or how those behaviors could be influenced via means such as different feedback mechanisms or goal setting. Other work has examined how energy use could be reduced (e.g. Hargreaves et al. 2010; Mack et al. 2019). Previous research examining social and psychological attributes has largely focused on analyzing issues such as dominant practices, personal values and attitudes, and how those may shape their energy consuming behaviors (Martinsson et al. 2011; Namazkhan et al. 2019; Shove and Walker, 2014). It has long been established in the literature that for example possessing environmental values does not automatically equate to reduced energy use in the home (e.g. Anker-Nilssen, 2003). A far narrower body of evidence has looked expressly at "conflict," especially when focusing on how household energy use in "smart homes"[1] and how that may cause tension and potential conflicts between different household members or groups (e.g. Hargreaves et al. 2010).

Yet the potential for social conflict within homes, communities and cities using energy is potentially grave, for it could interfere with the shift to energy services in a world moving in the direction of energy prosuming, decentralization and increasingly connected smart systems (Brisbois 2019; Parag and Sovacool 2016). Social conflict within households, or between households and communities, could also complicate and negatively shape the ability for decentralized energy supply or energy service models to contribute meaningfully

[1] We define a 'smart home' following Balta-Ozkan et al. (2013: 363) as being a home which "allows for remote electronic control and management of smart appliances (heaters, air conditioners, washing machines etc) and represents the convergence of energy efficient appliances and real-time access to energy usage data, facilitated by a network of sensors and computers".

to community owned energy systems or efforts at pushing energy democracy (van Veelen and van der Horst 2018; Szulecki 2018; Delina 2018). As Shin & Woo (2009: 2331) wrote more than a decade ago, in a shift towards smart homes, for instance, "identifying and resolving the conflicts of multi-users are complicated and crucial problems which need to be considered."

In this study, we seek to build on previous research on smart homes by looking at how the provision of "smart" and "low-carbon" heat has led to various types of domestic conflict. Our main research question is: how might the provision of smart, low-carbon heat lead to potential conflicts within homes? To provide an answer, we draw from three sets of primary household data—diary studies and blogging, telephone interviews, and in-person interviews—as part of a novel Living Laboratory involving 100 homes across Birmingham (West Midlands), Bridgend (Wales), Manchester (Greater Manchester), and Newcastle (Northumberland) in the United Kingdom (UK). Although we believe our results can certainly inform theory and aid in conceptual development, the aims and objectives of the study are more empirical, seeking to document the lived experiences within the Living Lab on smart heat, and also seeking to reveal the scale, scope, and intensity of household conflicts that occur. It fits the recent call from Sovacool et al. (2018) for articles that advance *empirical* novelty alongside those that seek to advance conceptual novelty or methodological novelty. In doing so, we see our article also as a mix of exploratory and confirmatory analysis, for we will show how it validates some previous findings on conflict, but it also challenges other sets of findings.

Reflecting further, our primary contribution is to more systematically and explicitly examine conflict as phenomenon, topic, and theme *centrally*, rather than peripherally or implicitly. For example, neither the burgeoning literature on capabilities nor the more established social practice literature tends to actively account for conflict. Prominent work on capabilities (Day et al. 2016) mentions conflict in passing only in terms of the conflicting high-energy consuming needs of the Global North contrasted with the growing energy consuming needs of the Global South, which germinate in tensions over greenhouse gas emissions and levels of economic development. Moreover, in laying out the dynamics of social practices, some of the key literature (e.g. Spaargaren 2013) mentions conflict only insofar as households may face tensions in incorporating technologies into their routines and rules. Other core literature fails to use the word "conflict" at all (e.g. Shove et al. 2012; Shove 2010). Similarly, Groves et al. (2016) discuss transforming social practices towards

sustainability, and how that transformation can create conflicting time pressures with the use of appliances, but not conflicts between people. Analogously, work on smart homes or enhancing control over energy services neglects comprehensive treatment of conflict. In their examination of the barriers to smart homes, Balta-Ozkan et al. (2013) never once use the word "conflict," and also frame tensions mostly in terms of interoperability and security. Nor do Fell et al. (2014) use the language of "conflict," instead focusing on aspect of "control"—and in our study, much of that control is latent or shifted to technology such as smart controls (meaning Fell et al.'s findings have less relevance for our topic). Demski et al. (2015) are noteworthy in actually mentioning "conflict" as it relates to public values and social transformation of energy systems, but they frame it only in terms of public perceptions generating global conflicts (i.e. violence), not a focus such as ours on private conflicts in the home. In that regard, Hargreaves and Middlemiss (2020, p.n/a) argue that social relations have a prominent role in shaping energy demand but that often research has focused on individual behavior and ignored that "households have shifting internal dynamics, porous boundaries and are related to others in often complex ways", impacting energy demand.

The paper proceeds as follows. In Section 2 we review previous literature that has touched on energy use and conflict. Section 3 discusses our research design, including our methods of mobile ethnography, telephone interviews, and in-person interviews, as well as details of data analysis. Section 4 documents inductively and empirically the presence of five different fora of thermal conflict across twenty specific examples, which we then discuss in Section 5 in relation to how they differ by location (intrinsic vs. extrinsic), type (preference, activity and attitude) and values (hedonic, egoistic, altruistic, biospheric). We conclude our analysis in Section 6, providing insights for the development of further behavioral models on energy use.

2. Literature review: Previous research on household energy demand and conflict

Energy use in the home is complex. As we outlined in Section 1, a large body of research has examined domestic or residential energy use, yet giving less emphasis on how energy consumption within a smart home could lead to conflict (or, at least, actively using the word "conflict"). By conflict, we mean the interaction of people with oppositional goals, aims, and values (Niemantsverdriet et al 2017). In their classic work, Deutsch (1977) wrote that conflicts can arise not only due to inequality of controls over resources, or disputes over beliefs, but due to differences in preferences and values.

To assess how energy demand patterns may create or intensify conflicts in the smart homes, it is helpful to begin to unravel what exactly it is that energy services, such as lighting, space heating, or refrigeration, provide, as well as who the actors are. Day et al. (2016) compellingly write that energy services connect intimately with "basic capabilities" such as maintaining good health or being educated, and "secondary capabilities" such as washing clothes, accessing information, or using machinery. In terms of actors or archetypes of energy users, based on research with focus groups in Germany, Scheer et al. (2017) talk about a range from those who are "uncompromising," i.e. fixed and firm in their views about energy technologies and services, to those who are "weighers" and will change their views or preferences based on context. Given that energy services become a proxy for doing diverse sets of things, across different archetypes of actors, the things that they enable can sometimes conflict—with each other, or with other household members.

Based on research surrounding energy demand and conflict, which we summarize below, we propose an approach to examining energy demand conflict in relation to *location* (relationships within and outside the home) and *type* (preference, activity and attitude/value).

2.1 Potential energy demand conflict by location

A number of previous studies have examined energy use and conflict—using that express word—by location, examining relationships either within or beyond the home. These studies have for example focused on examining relationships between different groups within the home, such as children and parents. Many of these studies have been conducted with small or limited datasets, and for short periods of time. Fell and Chiu (2014) for example examined the differences in energy use between parents and children. Using separate child and parent focus groups (two groups in each category with a total of 15 participants), they found little evidence of parents getting children to save energy, but there was anecdotal evidence that in some cases energy consuming behavior by children (e.g. watching TV and playing video games) could in fact avoid family conflict by freeing up valuable time for busy parents (Fell and Chiu, 2014).

In a study by Aguirre-Bielschowsky et al. (2018) (which involved interviews with 26 children and a supervising parent, and three focus groups with a total of 14 children) children were found to have a higher perception of their level of control over energy using appliances than what their parent(s) thought they had, with children reporting that they in fact used more energy than what their parents allowed them. Furthermore, in the same study, reminders (i.e.

repeated instructions on saving energy use through switching off lights and appliances, having shorter showers) were not always beneficial, leading to conflict in relation to parents nagging their children and children subsequently ignoring their parents, particularly when parents' own behavior was not consistent with their own instructions (Aguirre-Bielschowsky et al., 2018). Schmidt et al. (2014) found the opposite, that parents perceived of their own children as significant energy consumers, due to a lifestyle more attuned to using smart phones and computers. Boudet et al. (2014) surveyed 324 children and 224 parents and found that parents can play a role in influencing their children's energy consuming behaviours. However, their study examined only one gender—girls and in particular girl scouts. Snow at al. (2015) confirmed in a study of 12 families given an energy awareness and management system, that awareness of energy consumption was not a predictor of energy saving behaviour change. Particularly in a family setting "*existing family dynamics can serve to complicate or negate otherwise rational energy saving intentions*" (p. 939), influenced for example by who takes control of energy monitoring systems within the home (Snow at al., 2015). In terms of multi-user contexts such as couples or families, Niemantsverdriet et al. (2017) and Shin and Woo (2009) have highlighted how such contexts can lead to conflict when multiple household members are using potentially interconnected devices and appliances at the same time. We class such conflicts taking place between people within the home as "intrinsic conflict".

In addition to relationships within the home, previous research has also suggested that there are relationships outside the home that influence energy consumption (see also Hargreaves and Middlemiss 2020). In addition to the literature on family relations, another focus of previous literature has been the relationships between tenants and their landlords (e.g. Ástmarsson and Maslesa, 2013; Bird and Hernández, 2012; Collins 2018; Melvin 2018). A key debate within this has been the landlord/tenant dilemma in terms of how to agree on a common approach to energy efficiency improvements and who should pay for those. While the landlord owns the property, the tenants are usually responsible for paying energy bills, and in many cases their bills are higher than in owner-occupied homes due to poor home energy efficiency (Melvin, 2018). Dillahunt et al. (2010), for example, examined 26 low-income households and found that while conflicts can exist between landlords and tenants over energy consumption (e.g. who reports faults, who fixes them, who pays the bill), these were more importantly linked to who has power and resources in a conflict, given that "*the material reality in which tenants live, combined with the social structure in which they*

operate have a concrete impact on the resolution of conflict" (p.154). More recently, Ambrose & McCarthy (2019: 165) found that as tenants were becoming more "*intolerant of cold homes and high bills*", landlords' attitudes towards improving the energy efficiency of their properties were also changing along these new cultural norms. We class such conflicts taking place between relationships that go beyond the home as "extrinsic conflict".

2.2 Potential energy demand conflict by type

In addition to literature on energy demand conflict by location, i.e. intrinsic within home conflicts and extrinsic beyond home conflicts, previous research has also examined energy demand conflict by *type*. Niemantsverdriet et al. (2017), for example, developed a typology to help examine what types of conflicts may arise from energy demand, using lighting as an empirical case. Their typology includes three categories of potential conflict according to their type (and severity): preference, activity, and attitude (Niemantsverdriet et al. 2017).

Preference conflicts are situations where people or household members are engaged in an energy demand practice but have different settings or preferences for that practice. For example, some household members may prefer a warmer home, some a tepid home, others a colder home. (Interestingly, Niemantsverdriet et al. 2017 found disagreements over the temperature preferences for lighting, too). Preference conflicts are the least severe of the three conflicts, because perhaps they are easiest to manage; they tend not to have a large negative impact within the household and users often resolve them via compromise. Sintov et al. (2019), for example, studied 112 households in the United States reporting findings of previous research on women preferring higher thermal comfort than men. They also found that when thermal comfort interactions were negotiated, women reported more conflict compared to men who reported more agreements and compromises (Sintov et al. 2019). While this is only one such study, Sintov et al. (2019) concluded that their study confirmed findings from previous research on the differences in thermal preferences between women and men (e.g. Eon et al. 2017; Becker et al. 1981; Karjalainen, 2007).

Activity conflicts arise when different household members want to use the same device—the heating system—but have different requirements or perceived needs. They conflict over the actual use of the heating system. Activity conflicts are more severe than preference conflicts because there is often only a single heating system in each house—the place of which is determined by the house's basic infrastructure. For example, a conflict may

arise between household members wanting to use the same room that holds a single source of heat (or temperature). Such activity conflicts can be resolved for example by better synchronizing activities, or people moving to different rooms or agreeing to different temperatures at different times. For example, Balta-Ozkan et al. (2013) found in focus groups with 60 participants in the UK that households considered knowing energy consumption by room, rather than by device, more useful in order to reduce consumption. The smart nature of the heating system itself can help in this regard, as it would enable users to set different temperatures in different rooms or to change temperatures automatically at different times.

Attitude conflicts are the third type, and the most difficult to resolve. This occurs when household members fight not necessarily over the functional use of heat, but the more symbolic or social nature of what that heat practice or use is inferred to mean. Heat (or light use) becomes a proxy for the person's attitude and character, influenced by their value base.

Work across psychology and sociology on environmental values in general has blossomed over the past decade, with multiple (and often competing) frameworks offered and developed, especially when applied to "pro-environmental behavior" or the adoption of new technologies (Sovacool and Hess 2017). Hards (2011), for example, explores a range of "personal environmental values" and how those values manifest themselves within different groups, i.e. climate campaigners. Demski et al. (2015) also identify a helpful catalogue of 15 "public values" and "value clusters" for energy systems change, such as efficacy and waste or environment and nature. However, in our work we are more focused on values in the home, as well as private values and domestic practices, not public values and public practices. Given this emphasis, work by Steg and colleagues (De Groot and Steg 2007; De Groot and Steg 2008; Steg et al. 2014) fits well, suggesting that most behavior, especially in relation to actions such as energy consumption within the home, cuts across four fundamental types of values. Altruistic values, such as equality, peace, justice, and helpfulness, are rooted in helping others. Biospheric values, such as unity with nature, environmental protection, and preventing pollution, are about respecting and helping the earth. Egoistic values, such as social power, wealth, authority, influence, and ambition, are about making oneself better off. Lastly, Hedonic values, such as pleasure, enjoying life, and gratification for oneself, are about giving one comfort or happiness. Given the multiplicity of values, attitude conflicts—which ultimately result from the differences in what values are given or attributed to heating and energy consumption—are the most difficult to address as attacks on these could be perceived as attacks on one's identity. An example could be one household member preferring it dark

for energy savings, but the other preferring it well-lit for wellbeing: the conflict becomes interpreted as one of environmental sustainability vs. health and safety.

2.3 Towards an empirical typology of household energy demand conflicts

Based on the above, we summarize potential smart home energy demand conflicts by *location* (intrinsic and extrinsic) and *type* (preference, activity, attitude). These are summarized in in Table 1 below, and we will return to these dimensions in our results and discussion sections (Section 4 and Section 5). One of the contributions of the paper is that we include also other relationships than children & parents, and tenants & landlords (which have been researched before).

Table 1: A typology for energy demand conflicts

Conflict location		**Conflict Type**		
Intrinsic	**Extrinsic**	**Preference**	**Activity**	**Attitude**
Conflict within relations in the home	Conflict within relations beyond the home	Preferences for certain heating practices	Needing to use heating system at a certain time	Differences in what values are given to heating and energy consumption
E.g. parents and children, couples, house mates	E.g. landlords and tenants, neighbors	Preference for warmth/coolness, wanting to keep a certain temperature	Location of heating source in the home, occupancy at home pattern, work pattern, study pattern, leisure time pattern	Creating happiness (Hedonic) Make oneself better off (Egoistic) Help others (Altruistic) Help the Earth (Biospheric)

Source: Authors

3. Research design: Interviews, blogs and interactive diaries with a Living Laboratory on smart heat

Our core research design revolved around a real-world and fully operational Living Laboratory. A living laboratory, or "living lab," refers to a user-centered social experiment with the aim of testing a particular technology, solution, idea or policy in a real-world or real-time environment (Korsnes et al. 2018). One European research council defines a living lab as:

> *A forum for innovation, applied to the development of new products, systems, services, and processes, employing working methods to integrate people into the entire development process as users and co-creators, to explore, examine, experiment,*

> *test and evaluate new ideas, scenarios, processes, systems, concepts and creative solutions in complex and real contexts* (JPI Urban Europe 2013: 3).

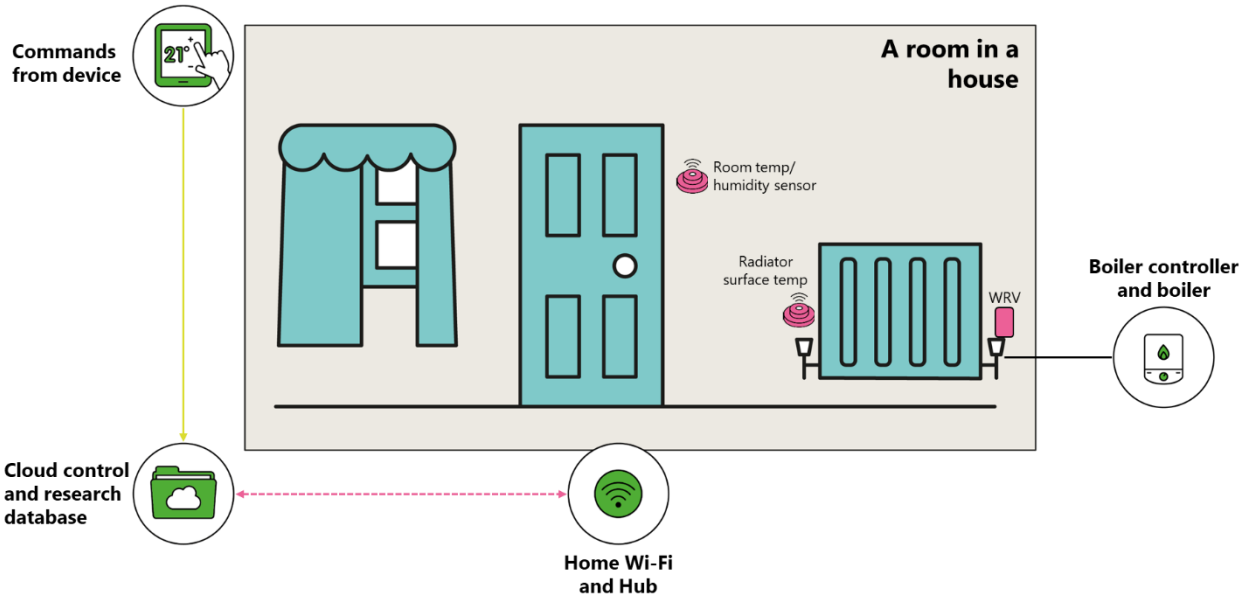
Voytenko et al. (2016) argue that living labs must satisfy three fundamental features: they are at local or small scales, reflecting challenges at a more discrete level of management; they are experimental or quasi-experimental, having different groups of participants; and they are participatory, creating platforms for direct user involvement.

Living labs have therefore become a new methodological tool for transforming users, or energy consumers, from observed subjects or end clients to co-creators of the research process (in theory at least). They also facilitate studying users in their complex real-life context (Claude et al. 2017). This makes it not only "user centered" but "carried out by the users," facilitating the creation and validation of technical (or policy) solutions in an iterative and interactive manner (Claude et al. 2017).

3.1 The Energy Systems Catapult Living Lab

Our study is based on data from the Energy Systems Catapult (ESC) Living Laboratory in the UK (Energy Systems Catapult 2019). This Living Lab consists of 100 homes spread across four locations—Birmingham (West Midlands), Bridgend (Wales), Manchester (Greater Manchester), and Newcastle (Northumberland). All households were provided with zonal heating controls that they could control from smart phones or any web browser. It thus involved the installation of an array of smart heating components into every home (See Figure 1).

Figure 1: Heat controls, applications, and scheduling available in the Living Lab



Source: Authors, based on Living Laboratory data.

3.2 Recruitment and demographics

As previously intimated, the Living Lab is made up of 100 households located in the four areas of England and Wales (see Table 2). The homes were recruited primarily by telephone recruitment carried out by Accent, an external agency and through a "refer a friend" campaign launched by the ESC. The agency contacted potential participants who had opted in to receive marketing calls and aimed to recruit them to join the trial. The participants were taken through a telephone screener to check their household and home's suitability in having the Smart Controls fitted. The ESC also ran a "refer a friend" recruitment method in which they recruited a total of 20 homes. All current participants were contacted via email and asked to refer any interested friends or family members to join the trial. These homes were then screened via telephone and booked in for a home survey to ensure their home is compatible with having the controls fitted. The demographics of the 100 Living Lab homes are also shown in Table 2.

Table 2: Composition and demographics of the 100 homes in the Energy Systems Catapult Living Lab

Location

- West Midlands: 26
- Manchester: 5
- Bridgend: 32
- Newcastle: 37

Age of lead participant

- 18-34: 8%
- 35-44: 30%
- 45-54: 31%
- 55-74: 28%
- Unknown: 3%

Household type

- Family with adult children: 10%
- Family with children: 50%
- Cohabiting couple: 24%
- Adults cohabitating: 2%
- Single adult: 11%
- Mixed generations: 3%

Types of Homes	Age of Homes	No. of Bedrooms
Bungalow: 3%	Pre-1945: 38%	1 bedroom: 1%
Mid-terrace: 13%	1945-1980: 33%	2 bedrooms: 16%
End-terrace: 5%	Post 1980: 26%	3 bedrooms: 46%

3.3 Data collection methods

The aim of the Living Lab research was to understand participant attitudes and behaviors when heating their home in order to help innovators design products and services that work for different households. Throughout the Living Lab, the ESC carried out research involving a range of data collection methods by three researchers. Participants had their homes surveyed and monitored, and they took part in a range of consumer research studies. As Table 3 reveals, these included research visits complimented by an extensive array of repeated data collection instruments, providing both qualitative data on the participant's experience of having the controls in their homes and their interactions when heating their home, and quantitative data on temperature, humidity and energy consumption.

Table 3: Technical measures and data collection techniques used in the Living Laboratory

Technical measures installed	Data collection measures*

• A "hub" which operates on its own internal wireless network, or z-wave; • Wireless radiator valves; • Individual room humidity sensors; • Individual room temperature sensors; • Individual radiator sensors; • Central boiler controller; • Utility flow meters; • Water pipe sensors; • Repeater to boost the signal from the hub to devices around the home; • Batteries.	• A pre-installation telephone interview; • Undirected diary studies and blogging, done in written and video forms; • Directed diary studies and blogging, done in written and video forms; • Semi-structured in home/telephone interviews; • Standardized surveys to cluster outlooks, behaviors and motivations of the entire group; • Measurements of temperatire and humidity in each room and radiator • Measurement of gas and electricity consumption • Measurement of user interaction with their heating controls.

Source: Authors; *Note that this paper only reports on qualitative data collected at the Living Lab.

For this particular paper, three sets of primary qualitative data from the Living Laboratory were utilized to document and confirm the presence of thermal conflicts: (1) telephone household interviews, (2) undirected diary studies and blogging along with directed diary studies and blogging, and (3) at-home in person household interviews.

First, *telephone interviews* were carried out by three researchers during the pre-installation phase of the controls and for reviewing heating service designs. The calls enabled the researchers to disseminate complex information and gather qualitative feedback from participants. The semi-structured calls provided participants with the opportunity to raise ad hoc comments and share their questions and experiences with the researchers. These interviews lasted approximately 60 minutes, with all homes involved in a pre-installation call and 42 participants taking part in a call reviewing tailored options of a heating service.

Second, *blogs* were used to record household experiences of having the controls in their homes and their interactions when heating their home. Indeemo, a mobile ethnography app, was used to set participants ongoing research blogging tasks. The tasks set on the blog included: regular video tasks capturing changes made to heating schedules and the reasons for changes; feedback on the cost feature on the controls; reviewing their experience on the trial and feedback on heating service designs. The blog allowed the researchers to capture

feedback from most of the homes in the Living Lab, with 75 signing up to the blog and providing updates during the trial. Over half of these trialists, provided weekly updates during the Winter period. As the blogging tool provides live screen recordings of the changes made by participants, the researchers were able to see the users interface as well as reasons for changes. This feature provides information that is not as easily captured in written posts or home visits. Given some respondents treated their blogs as a diary, we sometimes use both terms when describing this data source.

Third, *at-home interviews* were conducted with a sub-sample of Living Lab participants to provide a deeper understanding into participant perceptions of "comfort" in their own homes and what an ideal low carbon alternative system or service would look like. 26 participants each took part in a 90 minute home interview. Home interviews provided researchers experience of the environment of the trialist and more contextual understanding of their heating usage in the home. These interviews were used to understand the captured sensor data relating to the temperatures, spaces and times participants heated their home. These data were then used to understand the design of low carbon services and the needs and motivations of trialists when considering any new heating system or service.

All three methods were fully transcribed, anonymized, and then placed into an online archive we colloquially referred to as the "deep dataset."

3.4 Data analysis

Perhaps obviously, the data collected via the blogs/diaries and interviews was not explicitly focused on conflict, but instead the day-to-day workings of the homes in the Living Lab and the overall preferences, practices, and satisfaction levels of respondents. All in all, the research methods resulted in transcripts with thousands of comments and statements across hundreds of pages of text. Our goal in this paper was to extract from this deep dataset a focused look on conflict.

To do so, one member of the research team—and only one, to avoid possible issues with a team of coders or inter-coder reliability—thematically searched the deep dataset for instances of conflict. They searched for the six terms "conflict," "preferences," "arguing," "tension," "complain" and "disagreement" within the data, and then shared the results of these transcripts with the remaining authors. (Admittedly, other terms could have been used that were not searched for, such as "whining," "nagging," "moaning," or "fighting," parameters that could have altered the composition of our findings). The authoring team as a

whole then examined this subset of the data and discussed which examples seemed apt or most relevant for our research aims and objectives. Thus, other difficulties with smart systems experienced by homes that did not fit within a the conflict framework of location or type of conflict (see Table 1) were not examined, nor were instances not covered by the use of the terms conflict, tension, or disagreement.

Although our resulting body of evidence discusses 20 instances of conflict across 20 homes (or a rough 20% of the Living Lab), these results are from a purposive sample rather than a representative sample. These 20 homes show us varying degrees of conflict but reflect a small number of total examples or comments, which numbered in the thousands of pages of interview and blog/diary text mentioning it. Indeed, data for this paper was collected from just under 1700 blog posts, 26 home interview transcripts (made up of approximately 10000 - 15000 words each), and 42 consultation call transcripts (ranging from approximately 4000 - 8000 words each). We label our results as "conflicts" rather than mere tensions because they do represent conflicting goals over the cost and provision of heat, or conflicting preferences about heating settings. We have also taken examples from different homes, so that no single home or respondent is overrepresented in our results. We present each data below by source (diary/blog and interview) before then positioning our results in a discussion of conflicts by type.

3.5 Limitations

Although we trust the study's results in terms of accuracy and completeness, our approach does have a number of notable limitations. The 100 Living Lab homes are not representative of the UK, as the study did not include homes in fuel poverty or social housing blocks, consigning respondents to the middle and upper class categories in terms of income. Further, involvement in the Living Lab was geographically constrained, having to be located in one of the four areas of Birmingham, Bridgend, Manchester, and Newcastle.

Furthermore, respondents were not asked directly about conflicts, they were not prompted to discuss them which means all of our results and examples of conflict emerged organically or naturally from the Living Lab. This means they had to be inferred inductively by the research team, rather than directly queried at, or solicited from, respondents. As a plus, this means our examples of conflict were not prompted, they occurred organically and without intervention on behalf of the research team. However, their rather spontaneous nature makes it difficult to discern whether they reflect deeper, recurring household issues or are

rather isolated and minor occurrences. In simpler terms: the researchers noticed conflict coming up as an unprompted theme during data collection, and then decided to perform a more thorough analysis to find out more.

The ESC is bound by strict ethics and confidentiality agreements that err on the side of protecting the privacy of participating homes. Therefore, we are unable to offer interview schedules and topic guides due to ethics and approval constraints at the ESC, although we are able to reveal that these guides asked homes about their preferred temperature settings, their heating practices, their preferences in terms of future heating options or plans, and any issues or challenges that arose concerning their smart heating system.

Lastly, the data we utilize in this paper is qualitative, focused on the lived experiences and household interactions within the Living Lab. It is not quantitative in any statistically significant sense, which means we did not adhere to an experimental or quasi-experimental design to interpret our findings, nor do we attempt to translate our findings into statistics or effect sizes. Moreover, we did not make an attempt to correct, normalize, or weight the statements from participants, and instead treat all responses as valid and of equal merit. We do not show for example which conflicts may be deemed more or less important by respondents; nor do we show how they may interact and intersect with one another. We instead present them of equivalent status and simply co-existing. Also, although we treat values as fairy static for the purposes of our study, in reality few people sit statically within a value cluster and there is capacity for conflict within a person rather than between persons (Groves et al 2016; Demski et al 2015; Day et al 2016). Many of the instances of conflict mentioned in our analysis do seem to have an internal component, but our data presented is not a direct recording of conflict in situ but rather a subjective accounts of individual participants, who are to greater or lesser extent concerned for the comfort and wellbeing of others in the home. It is therefore subjective perceptions of conflict rather than independently objective account of it.

4. Results: Documenting thermal conflict by location

Notwithstanding these limitations, and drawing from our Living Laboratory data, we present in this section of the paper thermal conflict in terms of location, i.e. examining intrinsic and extrinsic conflicts. Intrinsic conflicts include those that occur within the home, while extrinsic conflicts include those that go beyond the home. We then discuss these in

Section 5 in relation to the three conflict types of preference, activity and attitude. Table 4 offers a summary of these findings.

Table 4: Thermal household conflicts by location and type

Conflict location		Conflict Type		
Intrinsic: within home	**Extrinsic: beyond home**	**Preference**	**Activity**	**Attitude**
Parents and children Hosts and guests Room mates Spouses/partners	Landlords and tenants	Preferences for certain heating practices	Needing to use heating system at a certain time	Differences in what values are given to heating and energy consumption

Source: Authors

4.1 Intrinsic conflicts within the home

We identified intrinsic conflicts, i.e. those that took place within the home, such as those between parents and children; roommates; and spouses or partners, which we report below.

4.1.1 Parents vs. children: "I'm boiling"

Our first form of intrinsic conflict involved parents and their children. One mother wrote in her interactive blog that she often conflicts with her nine year old son over turning the heat off and on. A father also joked in a research interview that he is constantly battling with his son over the temperature of their rooms:

> *Because my son, if it's warm he will make sure that you know that he doesn't like the heat. His ears go red, so he exclaims 'Get them off, I'm boiling.' Yes, so in his room, it's not that I'm a poor father, you'll see that there's no heating on in his room. I say, 'Listen, social services are going to come around, because the guys are monitoring what I use, and you're not getting any heating.'*

A third household discussed in their blog how their children rely on their mother to do everything, leading to added stress or at least dependence in the home for "mum" to do everything (and an activity conflict):

> *Mother: When I was [away], I could do everything sitting there. It was actually really good. My son would ring to ask about the heat [from back home]. I told them all to download the app and nobody will do it, so they just leave it to me.*
>
> *Researcher: You just do it from there?*
>
> *Mother: Yes. It's like, 'Mum, can you turn the heating on?' 'You could do it but, yes, I'll do it for you.'*
>
> *Researcher: Don't have their own phones?*

> *Mother: The sixteen-year-old doesn't at the moment. He's going to get one now for his sixteenth.*
>
> *Researcher: How do you think it would work if they did have the apps on their phones? Would you lose control of the heating completely?*
>
> *Mother: They're too lazy.*
>
> *Researcher: So, they wouldn't bother?*
>
> *Mother: I think if my daughter was here, she would, because she likes everything in order. She's a bit like me. My old one, I've told him so many times to download that app and he says, 'What difference does it make? You've got it on your phone. You can do it.'*
>
> *Researcher: Mum can do it.*
>
> *Mother: Yes, mum does everything.*

Another household discussed actual conflicts over thermal settings, with one liking it cold and another liking it warm (a preference conflict). A final household confirmed a similar trend in their blog, writing that:

> *Husband: I don't really feel the cold all that much, but my wife and my daughter do. Especially my wife. I can quite happily watch the TV in the cooler temperatures, but my wife, when we sit down of an evening, likes to have it nice and warm. Now, with my daughter, she really does feel the cold.*
>
> *Researcher: She has the erratic work schedule, doesn't she?*
>
> *Husband: Yes. So, it's up and down. It's never always the same, but we always try to have that block of a day so that roughly when she's coming in or just after she's come in, then the heating should be on at that point. More, at least, anyway. So, the heating's, kind of, ready for her.*

This exchanges underscores three competing preference conflicts between a father, a mother, and their daughter, with the father ensuring that the house is kept warm while also being willing to compromise his own comfort levels for others.

4.1.2 Roommates vs. roommates: "Have you been happy?"

A second form of intrinsic conflict involved roommates and each other, usually over tensions in different temperature preferences. As one household mentioned in an interview:

> *I house-share with my best friend but, to be honest with you, although I've shown her how to use the system, she pretty much leaves it to how we've had it set, certainly over the winter months, wasting heat. I've constantly said to her, when we've been trying to give updates, 'Have you been happy with the temperatures?' but she doesn't want to change.*

Another housemate reported, in a separate interview at a separate home:

> *Obviously, I want to have it warmer for going to bed, but not too warm because of headaches. But the bright bedroom is where my friend stays. She likes things hotter than I do so. Hence, why the temperature is 22 to even 24. Same again in the evening. I have to take the chill out of the room before she goes to bed.*

This reveals the presence of consistent preference, and activity, conflicts between roommates over desired winter temperatures as well as the use of heat for comfort and managing headaches.

4.1.3 Spouses and partners: "I've never had the house so hot"

Our third form of intrinsic conflict, perhaps the most prevalent and recurring, concerned spouses or partners fighting with each other over heat. This occurred in many different forms and across multiple households.

As one wife noted in her blog, she had to monitor heat but her husband could not be bothered to turn it on after her operation, and was more "careless":

> *Wife: [My husband] never used to ask about the heat. But in February, it was freezing. The plan was always that the girls would go to my mum's and she would take them to school. My daughter had a migraine, my eldest, they had to come here to look after her. My husband comes with me, because I'm having major surgery. I'm not out of recovery until 4:30. I said to him, 'How do I turn the heating up?' The heating was off in the middle of the day, as normal schedule, and it was freezing. My mother was in the house and they rolled out the blankets because they were all in my house freezing because I was there under general anesthetic and my husband wasn't bothered. So, he's never downloaded the app onto his phone, he doesn't know how it works, he hasn't touched it.*
>
> *Researcher: Even when it's freezing, he's not bothered?*
>
> *Wife: Well, there's only been a couple of times where I went out and left him and the kids at home. 'Oh, I'll just turn the heating on for them.' He hasn't asked me to, I thought. Show them how to do it, they'd be stuffed. That's one thing that I wish could improve. That's the only downside to it, I'd say. Not for me, because I'm always in control, but for other people, and my husband doesn't really do good [sic] with technology.*

Another wife noted on disagreeing with her husband over temperature preferences in an interview, remarking that "*my husband likes the bedroom warmer than I do, he thinks it's great we have the trial so he can make it really, really warm. I've been on holiday for one week without my husband and for him that was fabulous because he's just got the heating on when he wants it. It came on when it should have done and so for him, it was a big advantage not having to worry about how he's got the heating on and off while I'm not here*."

An additional husband stated in an interview that "*there's a divide in this house because she's cold and I'm always warm*."

However, another household mentioned the opposite, that the husband wanted it warm and the wife cold. As they remarked in an interview:

> *We have opposite views as husband and wife with regards to the temp of the rooms. My hubby would turn the manual thermostat to the highest setting 30 degrees!! This is an ongoing disagreement between us. As my view was when he sees temperatures that high abroad, he'd want the air conditioning on!*

Still other households mentioning conflicts between partners or spouses centered on feelings of laziness or specific practices such as bathroom towels. One husband mentioned in his blog that "*My wife will ask me to control the heat for her, she's got it on her phone, but she's just lazy*." Another household talked about conflicts over the bathroom, with a respondent saying in a blog that "*I like the bathroom hot, the reason being, it dries the towels and we haven't got a window in our bathroom upstairs so it's to hold the condensation, but my wife does not. Although she said the other day, 'I've never had the house so hot.' So, that means by bill's going to be more expensive*."

4.2 Extrinsic conflicts that can reach beyond the home

We identified extrinsic conflicts that go beyond the home and those include conflicts between hosts and guests; and landlords and tenants.

4.2.1 Hosts vs. guests: "Too cold for visitors"

A first form of extrinsic conflict involved hosts versus guests, notably visiting in-laws or hosting for visitors and parties. As one household explained in their diary:

> *Household member: I always turn the heating on when my parents come over. I don't really bother about that. It's just so the house is warm. It's not just parents, it's any visitors to the house.*
>
> *Researcher: Any visitors?*
>
> *Household member: Yes, really.*
>
> *Researcher: So if you know in particular if a person tends to be sensitive to the cold or is it just for their comfort you'd prefer to put the heating up?*
>
> *Household member: In all honesty, I think it's for our comfort. We wouldn't let the house go cold anyway and if people come across, it's the same as us. They've got to be comfortable same as me.*

Another household confirmed this practice of heating the house for guests, especially raising the temperature by a few degrees for in-laws:

> *If my in-laws come, I'd make sure that the house was warm for them, because, again, I don't want them thinking, 'God, I went to [a friend's] house and it was freezing!'*
>
> *Researcher: Okay. So how warm do they like it?*
>
> *Household member: Well, I know what I would set it as, like, nineteen, twenty degrees is really warm. But I will do it for them. For me, I like seventeen, eighteen degrees is more comfortable. When I am cold, and by myself, I wouldn't put it up a couple of degrees, I'd make a cup of tea instead.*

A third household commented in an interview about turning up the heat for their visiting mother:

> *When my mum was here, her not being able to turn the heat up was quite a problem. My mum was like 'It's freezing.' 'We're freezing.' It's like, oops, need to turn it up for mom.*

A fourth household stated in a research interview that: "*Family members have come round, they have said that house is cold. I find it ok but too cold for visitors. I will put the heating on just for them in lounge*." One household, in their blog, even discussed a more active conflict over a visiting grandmother:

> *Researcher: How have you found the colder weather?*
>
> *Husband: The bills have been a little bit higher than normal, because of, obviously, the cold weather. The other thing that's happened, as well, my mother-in-law came over. So, she stayed for, I think it was about six weeks or so, and she was staying in the extension room. We don't normally heat that room, so were constantly having it on, literally 24 hours a day. So, that made the heating bills creep up. I know for a fact that when my mother-in-law was at the property, the heating was on in the bedroom, it was almost on every day. She's fairly old and elderly people tend to get cold very, very quickly, so it's more comforting for her. Even though both me and my wife, we were both at work and the kids were at school, we still had to have that heating on, literally 24 hours a day, as such. I was saying to my wife, actually, 'I don't know why she always comes in the winter. Why doesn't she just come in the summer and do everybody a favor?' (Laughter). It's the cost, as such, so I'd probably put it down to that.*
>
> *Researcher: It's an interesting thing.*
>
> *Husband: Yes, with my in-law here, it was about £130 a month, but it went down to £47 after she left.*
>
> *Researcher: Did you think about restricting the heat?*
>
> *Husband: No, unfortunately not. In my eyes that would be a good thing to do, to restrict, but in my wife's eyes and the kid's eyes it's kind of, 'Oh, we don't want to be*

> *doing that.' It's because we can afford it, I suppose. That's the sad part about it, because you know, you can afford something, so you waste it, basically. Which, when I grew up it was kind of like, everything had a price on it, so you wouldn't waste things. Whereas now it's kind of like, it's a bit of a throwaway market. Easy come, easy go kind of thing. … I think that's just a reflection of people's attitudes and mentalities.*

What is most revealing about this exchange is it even monetizes the cost of heating for the grandmother, a difference of about £80 in terms of a reduction in heating bills.

4.2.2 *Landlord vs. tenants: "I often suspend the overnight heating"*

A second form of extrinsic conflict, though less frequently mentioned, involved landlords vs. tenants. We hypothesize that this was less frequent only because the Living Laboratory recruited owner-occupiers, so the sample only included a few sub-lets. Still, a few of the participating homes lent out rooms to boarders and tenants. As one household explained in an interview, smart controls allows them to reduce any tensions that may arise with their tenant over heating preferences:

> *The best thing about the smart heating system is the adaptability. My tenant was away for a few nights and so I was able to cut down the heating on her flat without affecting our heating. I do find that I am constantly altering the schedule as although the tablet shows it has reached temperature it's actually feeling cold. It's quite difficult to get it exactly right. I know the outside temperature affects the inside but sometimes I just want to turn it on and off and not worry about what it's doing. It's nice because our tenant has very different preferences than us, and this allows us to control them automatically.*

Another household commented in an interview that:

> *We have now moved 4 of the room stats away from the radiators to see if this will give a more even room temperature. The warm up time is still a concern and I often suspend the heating overnight as it was coming on at 5am and waking up our tenant. We have had some tension with the tenant over the lower initial temp to see if that cuts down the warming up time.*

This clearly reveals activity and preference conflicts between those managing and paying for heat and those consuming it.

Our results show how that these can occur internally (intrinsically within household members) or extrinsically (with non-household members such as guests or visiting relatives, and between tenants and landlords). We do indeed see both intrinsic and extrinsic conflicts over heating. While three-quarters of our examples (n=13) relate to conflicts within the home—parents and children, roommates, landlords and tenants within the same house,

partners—one-quarter (n=7) related to conflicts and tensions over hosting strangers, guests, visitors, and in-laws to the home. The aspect of landlord-tenant relations found by Dillahunt et al. (2010) in relation to the material context of tenancy was different for our Living Lab, because in each case the tenants lived in the same house as the landlords.

4.3 Conflicts by type: potential preference, activity, and attitude conflicts

Overall, when one adds up the examples above, 20 distinct examples of a conflict (from 20 different homes in the Living Lab) were identified inductively from our data and summarized in Table 5. In this section of the paper, we reanalyze those 20 examples through the dimensions of conflict type.

Table 5: Twenty distinct examples of heating conflict in the UK

No	**Example**	**Location**		**Type**		
		Intrinsic Within the members occupying the same home	**Extrinsic** Going beyond the relationships within the same home	**Preference** E.g. for hot or cold temperature at home	**Activity** E.g. putting heating on or turning it off	**Attitude** Creating happiness (Hedonic) Make oneself better off (Egoistic) Help others (Altruistic) Help the Earth (Biospheric)
1	Mom and son conflict over heating	1		Son does not like heat	Turning heating off	
2	Father and son conflict over lack of heating	1		Son does not like heat	No heating in son's room as son turns it off	Hedonic but also altruistic (father wanting to keep son warm, joking about social services coming)
3	Son asks mom to put heating on for him	1		Son likes heating to come an at certain time	Son asks and mom puts heating on for him via a phone app even though son could have the same app	Egoistic (son is too lazy to put heating on himself)
4	One household member likes coldness, the other heat	1		One likes the cold, the other the warmth	One wears deer blankets when cold, the other turns up the heat	
5	Father heating for others in the family	1		Wife and daughter like it warm	Father makes sure heating is on	Altruistic (father keep warm for wife and have heating ready for daughter)
6	Roommate not using controls but leaving heating on	1			Not using heating controls	Biospheric (wasting heat)

7	Warming for roommate	1		Roommate prefers warmer temperature	Turning up heating for roommate to take the chill away	Altruistic (turning heat on for roommate)
8	Careless husband	1		Wife prefers warmer temperature than husband	Family members needing to use blankets as heating has not been on	Egoistic (husband does not care about others' comfort enough to learn how to use the heating system)
9	Different personal preferences (woman likes cold)	1		Husband likes warmer bedroom	Husband has heating on more while wife is on holiday	Hedonic (husband creating comfort while wife is away) OR egoistic
10	Different personal preferences (man likes cold)	1		Husband prefers colder rooms		Hedonic OR egoistic
11	Different personal preferences (man likes warm)	1		Arguing over temperature settings	Husband turns heating high	Egoistic (less worry about heat)
12	Husband calling wife lazy	1		Wife asking husband to put heating on	Husband puts heating on for wife	Egoistic (wife wanting to keep warm herself)
13	Hot bathroom and bills	1		Husband likes warm bathroom so towels dry better	Husband keeps bathroom warm even though wife does not like it	Egoistic (saving money/cost)
14	Women hosting		1	Visitors liking warm house	Turn heating up when visitors come	Altruistic (heating for visitors' comfort)
15	Hosting in-laws		1	Visitors liking warm house	Turn heating up more when in-laws visit	Altruistic (heating for visitors' comfort)
16	Hosting mother		1	Visitors liking warm house	Turn heating up more when mother visits	Altruistic (heating for visitors' comfort)
17	Hosting visitors		1	Visitors liking warm house	Turn heating up more when visitors come	Altruistic (heating for visitors' comfort)
18	Hosting grandmother		1	Visitors liking warm house	Turn heating up more when grandmother visits	Altruistic (heating for visitors' comfort) also Egoistic (less worry about prices for grandmother)
19	Turning heat off when tenant away		1	Tenant prefers different temperature	Adjusting temperature settings when tenant is away	

20	Heating waking up tenant		1	Tenant prefers different temperature	Moving room thermostats away from radiators and suspending heating overnight	

Source: Authors

Niemantsverdriet et al.'s (2017) typology on three types of conflict (preference, activity, and attitude) was based on their work on household lighting practices, but this typology maps equally well onto heating conflicts. We do see all three of these types of conflicts within our results, and even though we report them as separate, there are underlying links between all of them.

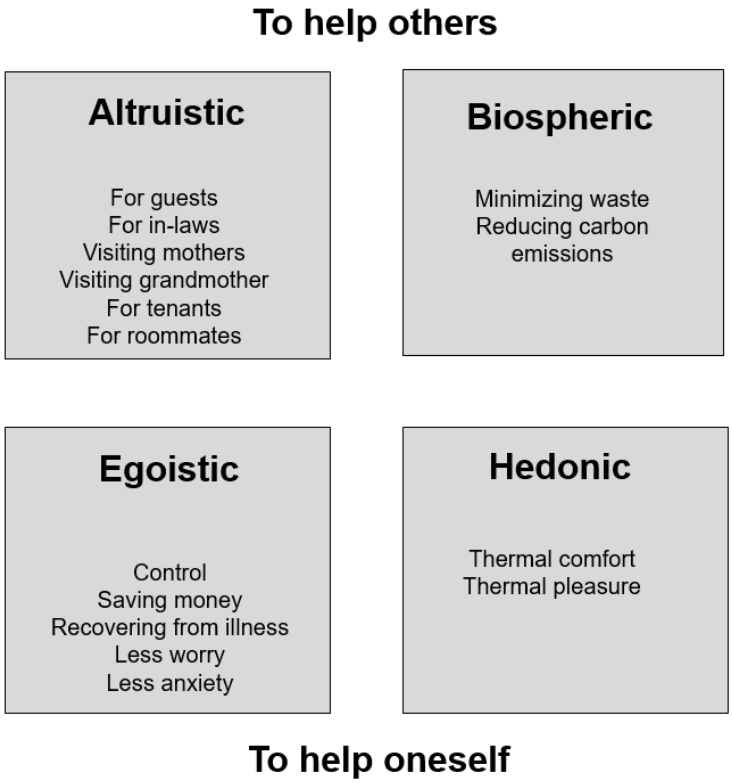
We identified preference conflicts in 19 cases, as Figure 2 indicates. Almost all instances involve parents fighting with children over temperature settings, or landlords and tenants having different thresholds of thermal comfort, or partners liking it hotter (or colder) than the other. In many of these cases, people were willing to forgo their own preferences to meet others' preferences, with parents for example agreeing to keep other family members comfortable by providing their preferred temperature.

Many of these preferences led people to act in order to reach desired temperatures. Many conflicts could be classified as activity conflicts, and related to people turning the heating system on or off, to putting blankets on or off, to leaving rooms or turning up or down temperatures, to one (a tenant) even waking up when the heating system turned on. With many of the activity conflicts, there was constant adjustment and renegotiation to heating controls as people sought the right temperatures.

Even though we could not always identify the most severe conflicts, i.e. the perceived attitudes and values underlying preferences and activity, in many examples these were clear. Perceptions of laziness, carelessness, or wastefulness within other household members were mentioned by respondents. Interestingly, as we see in Figure 3, many of our conflicts reflect altruistic values, for they involve household members trying to help others (guests, in-laws, visiting family members, tenants, and roommates). In these cases, people were willing to ensure others were comfortable, or they did not want to be seen as providing a cold experience in their home (in case of visitors for example). Only one of our conflicts reflects a biospheric value, minimizing waste, and even then it was not actively connected to climate change or the environment, but wastefulness of heat. Many of our examples reflect egoistic values such as saving money, enhancing control, or recovering from illness, with many

respondents feeling that others were only thinking of their own comfort at the expense of others. Many of our examples also reflect hedonic values such as enhanced comfort or immediate pleasure. We next discuss our findings and conclude making recommendations for further research.

Figure 3: Contrasting values behind household examples of thermal conflict (n=20)



Source: Authors

5. Discussion: The complexities of conflict and conflict resolution

Our study shows that thermal conflicts in the home differ in their *location* and/or *type*. Some are intrinsic to the household, occurring only within or among household members. Others are extrinsic to the household, involving visitors, guests, and visiting family or in-laws. We show that these go well beyond the tenant/landlord relations that much of previous literature has focused on (.e.g. Bird and Hernández 2012; Melvin 2018). Extrinsic conflicts may be more difficult to predict, however, as it may be difficult to determine the heating preferences of strangers before they enter a home. Yet intrinsic conflicts may be more difficult to resolve, given that they can be frequently occurring over a long period of time and fuel embedded family tensions or even create new ones.

Relatedly, we find that thermal conflicts differ in their severity. Some occur as more minor annoyances over preferences. Some remain centered on activities, and can be resolved by turning heating systems on or off, temperatures up or down, or wearing blankets. The most severe conflicts occur about attitudes and underlying values, where heating actions or preferences become a proxy for something else, and emit strong feelings about how a household members views another person as lazy, careless or wasteful. These attitude conflicts, can be extremely difficult to resolve when they become intertwined with personal identities, household lifestyles, and in some cases inflexible energy demand patterns.

Relatedly, initial conflicts do not always culminate or cascade into more intractable types of conflicts or dysfunction in the home. Some lead to conflict resolution, cooperation, and even further sensitives towards household members and acts of care. Many of our qualitative examples revealed householders, partners, roommates and hosts being generous, caring, thoughtful and much more besides. In short, such "thermal conflict", when viewed in the context of the many other issues that households have to negotiate on a daily basis and which aren't just about heat or energy, may contribute to keeping households together as much as it can break them apart. There is a dualism to conflict in that it can precipitate household or family discord or potential growth and development

Our study also shows that a variety of values remain attached to heating conflicts, with hedonic (self-comfort, self-pleasure), egoistic (saving money, control) and altruistic (helping others, making others comfortable) values almost evenly reflected across our examples. However, and interestingly, biospheric values such as protecting the earth or cutting emissions were rare and did not occur frequently; in one instance they only arose indirectly about waste rather than directly about climate change. Perhaps the implication here is that households value heat, and heating conflicts involve non-environmental aspects far more saliently than pro-environmental considerations. Moreover, environmental considerations (such as climate change) and cost are relatively rare causes of conflict compared to harmony, hospitality, or comfort. Though this is a qualitative study, our quantitative data bear this out as well.

Our study lastly demonstrates that thermal conflicts exist within a complex and dynamic sociotechnical or socio-material environment. Aspects such as heating fuels, technologies, and services are but only some of the important factors. Others include control (who controls the heating) or convenience (having a comfortable temperature setting or the

ability to set temperatures automatically), as well as monitoring (how heat can be tracked and visualized in real-time) and dependence (which person is familiar and has the requisite tacit knowledge to operate the system). Moreover, heating fuels and services, and notions of control, also intersect with employment patterns, working patterns, occupancy patterns, and differing levels of perceived thermal comfort. This complex environment can also see a tension between individual vs. household needs. Control of the thermal environment is only one aspect of broader household dynamics within shared homes. Here the needs and relationships between parents and children, hosts and guests, roommates, spouses, partners, as well as landlords and their tenants, become evident.

6. Conclusion

In this study, we drew from Living Lab data on heating use across 100 homes with smart heating controls. We identified inductively and qualitatively 20 separate instances of conflict across 20 homes (or 20% of the Living Lab) concerning thermal temperature settings, practices, or preferences, mentioned in household interviews, diaries, or interactive blogs. Our study revealed that heating conflicts within smart homes can vary by location, type and underlying values—which were both confirmatory (supporting earlier findings), and exploratory (challenging earlier findings or requiring further research), but all with clear implications for future research and policy.

Our study differentiated between relationships within a home and those that go beyond it (e.g. hosts versus guests), providing a promising step towards more realistic behavioral models that currently do not always take into consideration multiple relationships. The typology of location, type and values (building on the work of Niemantsverdriet et al. 2017 and Steg et al. 2014) could also be applied to other dimensions and domains beyond heat.

Furthermore, if it is true that families can fight over temperature dials, different thermal settings, and representations of what heat means within a household, then it may be that formal modes of conflict resolution—coming from communication studies, management, public policy, critical stakeholder analysis, or even peace studies—are warranted. Day et al. (2016) mention a list of compelling "intervention points" for how to enhance household energy practices. They refer to interventions related to "providing for particular needs," such as water heating or food preparation, and interventions related to "shaping or shifting expectations, customs, and practices," such as having social respect and maintaining

relationships. These intervention points become even more salient when placed into the context of thermal conflicts. Future research may want to explore not only modes of conflict resolution but also emotions and emotional stamina. People need to be able to handle conflicting emotions and work through disagreements as they come to adopt low-carbon innovations such as smart heat. They need to keep the determination to stick with it, thereby requiring, perhaps, the invisible skills of emotional stamina and conflict management. Our study implies that we might need to pay more attention to these aspects if we want to design low carbon solutions consumers want (rather than assuming everyone wants to save money/carbon). Future smart heat frames, messaging strategies, and marketing approaches may also want to consider emphasizing the non-environmental aspects of low-carbon heat.

We intended our empirical study to be a starting point, not an end point, for conflict-based research. New insights or ideas about where these conflicts come, so we can better comprehend how they play out in different times and places, and what their significance (positive or negative) might be for the roles of households in zero-carbon transitions would be an extremely important avenue for future research. Following from our findings, research and policy agendas need to be meaningfully shifted. Our study suggests that innovations such as low-carbon heat can lead to household conflict and in some situations dysfunctionality and anguish in ways that may ultimately result in a rejection of innovations; conflict and the emotional responses to decarbonisation ought to be explored in other contexts. Even when most households state that smart heating increases their sense of control, we still see the potential for conflict. Designers of smart home energy management systems may often assume one can automate heating control algorithms to deliver the comfort preferences of the household. However, this will not be possible if different occupants have diverse preferences. Careful design will be needed to enable households to navigate these conflicts, and avoid exacerbating them, or ensuring they lead to cooperation and resolution rather than bitterness and division. This could ensure that the introduction of low-carbon heat leads to harmony, rather than disorder and discord, in the home.

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